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# Sunder Axe: Encouraging Habit and Safe Use

Timothy Bromm

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# SUNDER AXE

ENCOURAGING HABIT AND SAFE USE

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Thesis 2015

June 1, 2015

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# ABSTRACT

By evaluating axe design based on tradition, functionality, and product use I was able to establish a series of problems related to current axe designs. These problems included an understanding of proper technique, accuracy, and user education. In order to address these problems, I used findings from the research and user testimonials to design and develop successful solutions. These solutions were then field tested to verify their validity.

# PROPOSAL

Axe design is dependent upon a number of factors that influence the parameters of product use and market acceptance. By evaluating axe design based on tradition, functionality, and product use, I will establish a collection of current design related problems. These specific problem areas will be addressed during a redesign process, where I plan to strategically apply the design process to resolve the issues at hand.

It is assumed that in the process of evaluating the tradition, functionality, and use of axes, that important cross-category interactions will be discovered. The initial categorical divisions are essential to focus my research, but commonalities will be highlighted and further explored.

A sensible order of operations would first include the assessment of axe tradition and history. This research will help to determine the various types of axes and their uses. Understanding the historical aspects will also show the evolution of the product over time.

The second operation of study will include research of function. This study will help determine the current uses for axes and help formulate a better understanding of the people who utilize them. In other words, I will be able to determine the market for axes based on functional characteristics.

The third operation will involve a study of use. Once I have an understanding of the market, I will be better able to narrow my research and study the abilities of the primary users.

Each of the three former operations will help establish a series of problems. These problem areas will be addressed through design intervention and new product development. Following the completion of my thesis, I will have a number of physical objects to represent the outcomes of my research and development.

# RESEARCH

Axe design requires a fully immersive research approach, including an understanding of the history, tradition, manufacturing, and emotional relationships that are associated with the product and its counterparts. Thorough literature reviews and a comprehensive collection of user testimonials and feedback were conducted to complete the necessary research.

## HISTORY AND EVOLUTION OF THE AXE

In his 1998 book, “The Axe and Man,” Charles A. Heavrin presents the first true man as *Homo erectus*. This is the first evolutionary stage of man where the slender shape of the thumb bone allows fingers to hold and form tools. *Homo erectus* used what is known as a Chellean Hand-Axe (Figure 1) as early as 600,000 BC in Africa and was believed to be made by chipping edges onto a pebble with a hammer stone. The hand-axe was held and used in the palm of the hand rather than with a handle, hence its descriptive name. In a more recent publishing, hand tools as old as 1.8 to 2 million years have been discovered in Tanzania, Africa (MacGregor 2010, p. 9). To an inexperienced eye, these objects may appear to be no more than stones with jagged edges, but they were discovered near “human” remains and the stones appear to have been formed by people.

Regardless of the inconclusiveness of the evolutionary development of the true human, the images shown throughout the Heavrin’s book represent axes clearly as they have evolved over time. There have been a number of parallel design iterations per time period, but what became

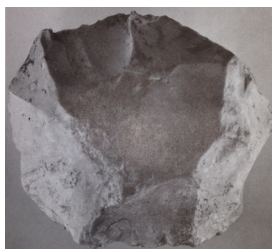


Figure 1: Chellean Hand-Axe (Heavrin 1998, p.11)



Figure 2: Fluted Axe (Heavrin 1998, p.41)

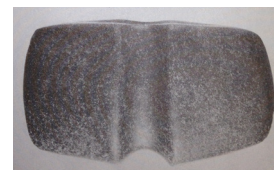


Figure 3: Double Bladed Axe (Heavrin 1998, p.41)

important were the subtleties that existed from one time period to the next. Throughout history, axe makers and designers have taken cues from past products, creating a cohesive and ancestral object.

Heavrin highlights axes of all different types of material including stone, copper, bronze, iron, and steel. The axes in Figure 2 and Figure 3 are also stone axes, specifically granite, and both axes have a groove carved into the stone. The purpose of this groove is to tie or “haft” a handle to the axe, which would often be accomplished with the use of reeds or thongs.

When copper began to be used as a material, the methods used for casting were not thoroughly explored. Some of the first copper axes, know as Flat Axes (Figure 4), were called such because when they were poured into an open mold they would come out flat. Molds were typically made by carving an opening into the face of stone, clay, or pottery.

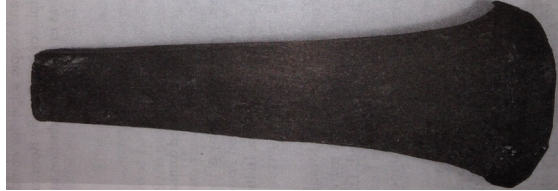


Figure 4: Copper Flat Axe (Heavrin 1998, p.50)



Figure 5: Copper Palstave (Heavrin 1998, p.52)

Once a common method was established for casting copper axes, people began to experiment with the capabilities of the material. The axe was eventually turned on edge and shallow flanges and ribs were hammered into the axe head. A new form of axe was born from these methods known as the palstave. A palstave (Figure 5) uses an L-shaped handle, which is similar to the one shown below with the socketed axe head in Figure 7a. It is slotted to accept the rear wedge of the axe head. The palstave also has a small stopper flange that helps reduce the chance of splitting the handle when the axe strikes wood or flesh (Heavrin 1998)

The next two iterations of copper axes include the winged axe (Figure 6) and the socketed axe (Figure 7 and 7a). There is a distinct evolution and visual connection that exists from the palstave to the winged and socketed axes. The winged axe has much larger flanges for the acceptance of a handle and the socketed axe evolves that concept even

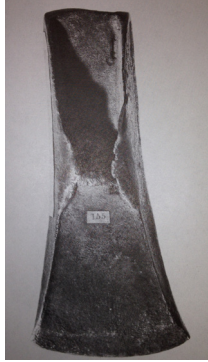


Figure 6: Winged Axe (Heavrin 1998, p.55)



Figure 7: Socketed Axe (Heavrin 1998, p.57)



Figure 7a: Knee Hafted Socketed Axe (Heavrin 1998, p.58)



Figure 8: Palstaves and Bronze Battle Axe (Heavrin 1998, p. 71)

further by enclosing the axe port all together. An interesting feature that was added to the socketed axe, known as a thong loop, assisted in the hafting process.

Many features of the axes that were made using copper continued to be used into the Bronze Age. Figure 8 shows a number of bronze palstaves. There is also a bronze battle axe in the upper left hand corner.

Iron was the next material that worked its way into the development of early axes. Cast iron has appeared in a number of forms throughout history, which ultimately led to steel, a common material used today. Early Scandinavian designs using iron followed the pattern of what was



previously known as the bronze socketed axe and was used up until the time of the Vikings (Brånby 1994, p. 7). The Vikings used a number of axes, primarily for battle purposes. However, wood-working tools were also needed. The image in Figure 9 shows a Viking Felling Axe, which would have been used for felling trees.

The last reference from “The Axe and Man” relevant to this research is the American felling axe. There is a rich history of American felling axes that often shows a strong personal tie between owners and their axes. Older axe manufacturers would only sell the axe heads, because most people would take pride in crafting a handle that fits their own personal needs. There have also been a number of variations of material used. One of the more common methods was to use a softer material, such as

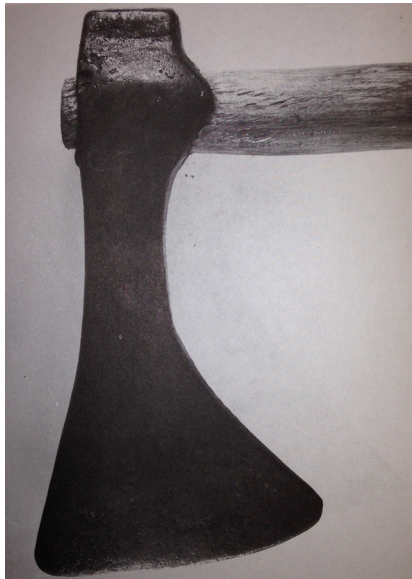


Figure 9: Viking Felling Axe (Heavrin 1998, p.88)

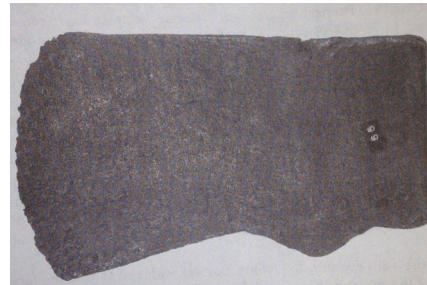


Figure 10: Single Bit American Felling Axes (Heavrin 1998, p.113)



Figure 11: Double Bit Axes (Heavrin 1998, p.125)

iron or low-carbon steel to create the body of the axe head, and then a high-carbon steel bit would be forge welded as the cutting edge. An example of an American felling axe can be seen in Figure 10. Single bit axe heads were common, but when the axe became prevalent for the logging industry, a double bit axe was supplemented for speed and balance (Figure 11). This double bit use for logging was a fad, due to the surge of saws in the industry. Today it is more common to own single bit axes or mauls for splitting logs.

Towards the end of his book, Heavrin says that “after 10,000 years,

the design of the axe has not changed dramatically. Of course, the evolution of the axe from stone to steel is certainly noteworthy, but what is more dramatic is the method of its manufacture.” (Heavrin 1998, p.162)

This quote speaks to the axe as a tool and the efficiency of its use. It was important throughout the process that the design did not lose the characteristics of what makes an axe, an axe.

## THE CHARACTERISTICS OF AN AXE

In order to maintain a traditional design, it was required to understand axes and the purposes of the various form decisions that have been made and improved upon throughout the evolution of the axe.

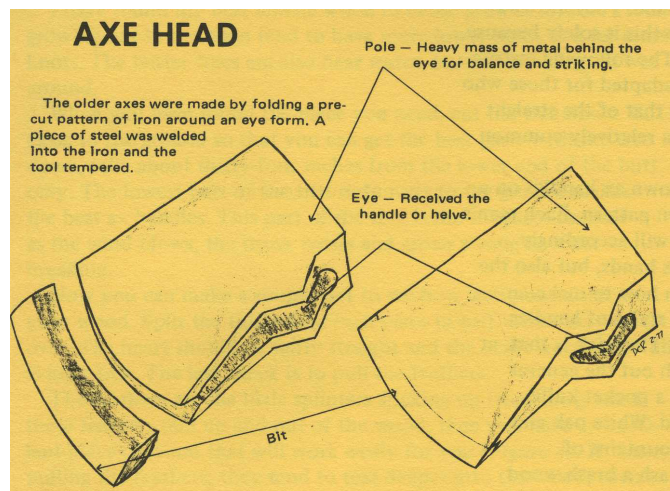


Figure 12: Components of the Axe Head (Reed 1977, p.5)

## THE AXE HEAD

Modern axes have a few characteristics that are common from one type to another. The diagram in Figure 12 demonstrates the various components that make up the basic structure of the axe head. A typical misconception is that the pole, which is more properly

spelled ‘poll,’ of the axe is meant to be used as a hammering surface in the instance that the axe head gets stuck in a piece of wood. Rather, the poll was implemented into the design of the axe head to act as a counterweight to the elongated blade. This counterweight improves balance and accuracy during the striking action. Hammering on the poll can easily damage an axe head.

Another topic that is highlighted in Figure 12 is one of the common methods for fabricating an axe head. In order to get a better understanding of the process of making axes, a dialogue was started with multiple experts in their various respective fields, all of which directly related to this thesis research. Early in my process, two blacksmiths local to Rochester, New York were contacted who have previous experience making axes.

The first person met with was Graham Carson. Graham is a professional blacksmith and professor at the Rochester Institute of Technology. He has worked on a number of knives and axes throughout his career. Carson uses both forging and stock removal methods to create his products. The second person met with was Candace Martens, the Blacksmithing Director at the Rochester Arc & Flame center, who devotes much of her lifestyle to metal working processes.

During the initial discussion with Carson, the process of making an axe head was discussed (Carson 2014). Traditionally, makers would use iron or a low carbon steel for the majority of the head. This was due to limited access and the value of high carbon steel. They would then fold the original bar-stock in half and insert a high carbon steel bit for the cutting edge. Martens expanded upon this concept by explaining her process for forging an axe head (Martens 2014). When she has the original bar-stock, she will hammer an indent into the middle of the bar. By doing this, she creates a location that will result in a handle hole when the metal is folded. Following the fold, Martens creates a forge weld and then inserts the cutting edge. She also opens up the handle hole to the desired size using a pre-made punch. An example of this can be seen in Figure 13.

According to Martens, it is currently common practice to make the entire axe head out of high carbon steel, due to the fact that the steel is not as valuable as it was in the past. Carson added that it is also common



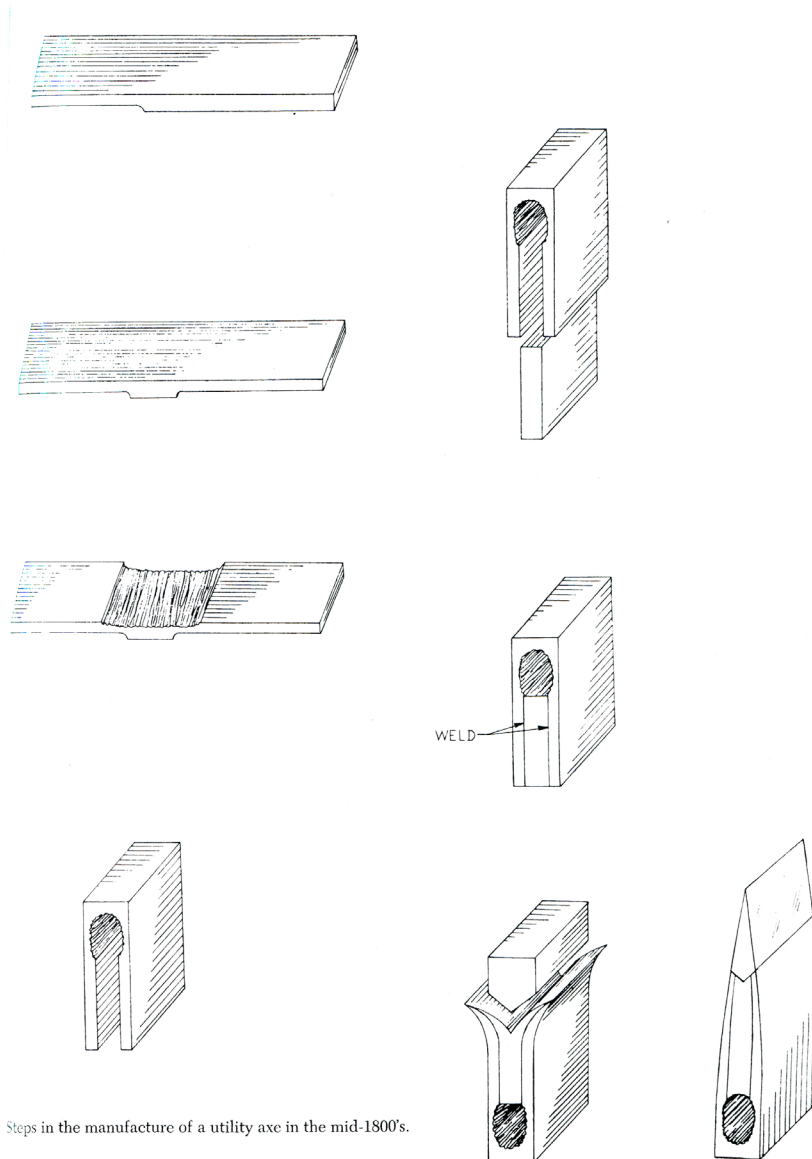


Figure 13: Forging an axe head using an added bit (Kauffman 2007)

to use stock removal for many axes. He admitted that some might argue that forging the steel creates a stronger bond within the material, but Carson has found that with the way most steel is currently processed you are able to get an equally high quality product using stock removal methods. Ultimately, it is dependent upon the quality of the starting

material and how it was treated.

Understanding current manufacturing methods was essential for the design process, so Best Made Company, a North American axe company that takes a lot of pride in the quality of their axes, was contacted. Peter Dudley, the man who oversees production of painted axes at Best Made Company, was able to elaborate on the methods used for mass manufacturing (Dudley 2015). Steel axe heads are forged from a single billet of tool steel. This chunk of high carbon steel follows its path



Figure 14: Axe and Halligan Bar

through a number of machines for the forging process.

The first machine is a punch, which cuts the outline of the axe head. The axe then moves to the forge to begin the hammering out of the tapered form of the blade. After going through multiple die cuts and forge strikes, including the entire eye of the axe being punched out of the billet, the final polishing is done by hand. Dudley said this handwork is frequently evident, considering some of the variation they see in final products.

Following the discussion about manufacturing, Dudley explained the way axes are designed and why they are designed that particular way. He noted that many modern manufacturers are finishing axes with a parabolic grind. In this method, a wide angle of about 80-degrees is made at the cutting edge, but then quickly rolls into a curved grind. This provides a small, wide, high-forced entry at the point of contact with the log, but then eases into the split.

Following the discussion with Dudley, Nick Zdon, the Director of

Customer Experience at Best Made, was interviewed (Zdon 2015). Zdon has the responsibility of doing proactive customer outreach, training for staff, and verbal and graphic communication with staff and customers, as well as teach educational courses to the public. Additionally, Zdon is a serious collector of axes himself and is knowledgeable about axes and their history.

The conversation began with a discussion regarding the subtleties of axes and how they have evolved over time. Traditionally, axe designs have been adjusted for use. During the American Logging era, axes were used for many different types of applications and varied accordingly. There were axes for felling, bucking, clearing land for roads, breaking ice, and even poison axes that would be dipped in a chemical to kill off trees when chopped. Additional examples of axes used during this period include rescue axes that were kept on helicopters to cut through sheet metal in the case of an accident and the axe/halligan bar combination that is often carried by firefighters. An example of this firefighter tool combination can be seen in Figure 14 from a visit to the Henrietta Fire Department in Henrietta, New York.

With regards to the amount of time that axes have existed, the creation of the splitting maul is a recent development according to Zdon (Zdon 2015). He considers it more of a “cousin of the axe.” For the most part, axes today are multipurpose tools. He said that felling has essentially been done away with following the implementation of the chainsaw. Zdon said the axe has become primarily for splitting logs, but it is versatile enough that it can be used for other activities as well.

An important observation is that the average user is frequently unaware of axe design subtleties and why they are needed. An example is the distinction between axe design based on geography. Zdon noted that American axes have a crown and centerline along the blade. Alternatively, European axe blades will be almost straight across rather than curved. He said that this is all dependent upon the type of the wood that is split. Typically the European species have grain patterns that split more easily than those in North America. The curve is helpful for removing the axe from logs that do not split in one strike, like those found many American species of wood.

Peter Dudley also discussed axe design being dependent upon the type

of wood that is being used (Dudley 2015). In short, he stated that 9 out of 10 times, people will return an axe because they try to split a log that is not meant to be split by hand. He said that part of the challenge of this is educating people to understand the limits of the axe and the log.

In addition to conversations with Best Made Co., the discussion with Candace Martens had significant influence over the understanding of axes and their evolution throughout history. As previously noted, subtle changes have occurred to axe design over time and the question was raised why these changes are primarily small, and not drastic in comparison. Martens addressed this by discussing the nature of the axe as a tool. She explained that regardless of how you look at it, many tools need to perform a certain function. Once a simplistic yet effective solution is determined, it is often looked upon for inspiration by others. Martens stated that when a function within a product is a dominant feature, there is only so much that can be done to alter that specific design (Martens 2014).

In other words, the axe has been designed to perform a specific function. Over time, designers and makers have looked upon the axes of the past and adapted them to their own needs. No matter what those changes might be based on – various crafting processes, reflections of personality, or any number of specific functions – the axe is designed to perform as a cutting or splitting tool.

## **HANDLES**

Several interviewees also elaborated about axe handles. Peter Dudley from Best Made Co., talked about how wooden handles are currently mass-produced (Dudley 2015). Best Made Co. uses a method called the multiple rotary carving technique, which allows a number of wooden blanks to be positioned and loaded so that each handle has its own router bit. These router bits are moving and cutting at the same rate, along the same path in space with relation to each of their wooden blanks. This is how multiple handles can be created identically with the exception of slight variations in the wood. Best Made Co. has made a point of requiring certain standards for their axe handles, so variations are slight and it is rare to receive a piece that has undesirable characteristics. Some examples of unwanted variations might be grain

runoff or steeply angled grain patterns.

Nick Zdon said that with regards to material, there aren't a whole lot of options currently available for American axes (Zdon 2015). For people looking to invest long-term in an axe, the handle needs to be replaceable and ideally needs to be made of a renewable resource. He commented on the quality of plastic handles and how even if they don't break easily, they get roughed up and can chew the hands causing blisters. For wooden handles, American hickory is a favorite species. Other types of wood have also been successfully used, such as ash, white oak, and wood from various fruit trees. Zdon said that overall if there is a story behind it, then that is the best reason for a particular material selection of the handle.

Before the forming and setting of plastic handles, people would attempt different ways to attach handles to the axe head. One method was to use an epoxy that glued the handle to the axe head. This created removal difficulties on the occasion that the handle would break. Currently, the most standard way for hanging an axe on a handle is to use wooden wedges that fill the precut slot and hold the axe head using a snug friction fit. Often this is finished with a serrated-steel cross-wedge that is hammered in to keep the wedge from rising out of its slot. Sometimes axes will come with a steel ring that is hammered in rather than the serrated wedge. Zdon attributed this form decision to the manufacturing process, not the function, as a rounded wedge is able to stand on its own for automated processes. With a wedge-shaped pin, it would need to be held in some way in order for it to be pounded into the wood.

Zdon spoke of two different schools of thought regarding the hardness of the wooden wedges used for axe hanging. One argument is that softwood can compress more, so it provides a tighter fit in the axe head. The opposing argument is that a hardwood can be hammered harder to insert the wedge farther into the slot, providing a more snug fit. Zdon believes this to be a really trivial argument and that either one has merit. He said he will commonly just use whatever comes with the handle, which is often poplar. There are also aluminum wedges that exist that Zdon thinks could potentially hold faster than wood.

Another interview was with Patrick Kana, a second year graduate student in the School of American Crafts at the Rochester Institute of

Technology in Rochester, NY (Kana 2014). Kana also spoke with me about the material characteristics of axe handles. Patrick as he has spent some time working for Best Made Company in Maryland with Peter Dudley.

Kana said that typically axe handles are made with hickory, ash, or white oak, which is consistent with previously reported findings. These species are highly durable, but are also somewhat flexible during impact. This is due to the make-up of the pores in the grain, as well as the composition of the lignin that glues the grain together. The flexibility significantly reduces the amount of reverberation that enters the hand following impact. Because the vibrations that enter handles on

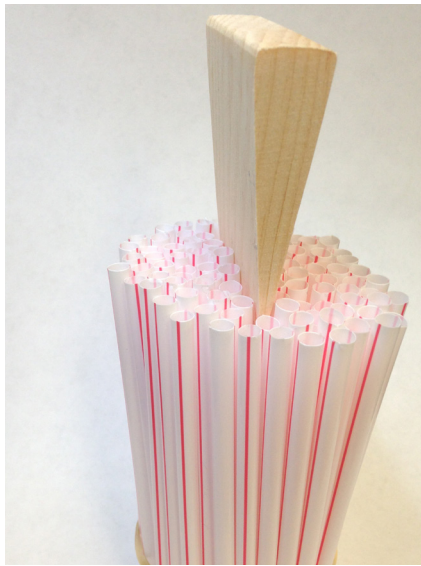


Figure 15: Small Wedge



Figure 16: Large Wedge



Figure 15a: Small Wedge entering straw log simulation

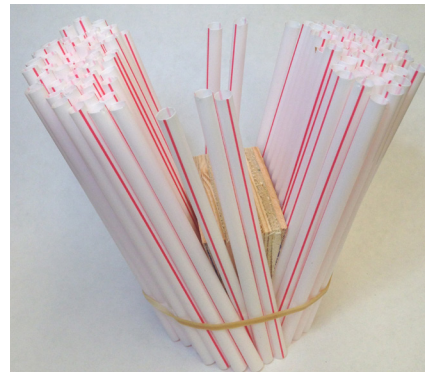


Figure 16a: Large Wedge entering straw log simulation



impact transfer throughout the material, metal handles are rarely seen. Wood typically dampens these vibrations and absorbs much of the force.

Though wood is a great material for axe handles and can be shaped in a number of ways, it has some significant drawbacks. One of those drawbacks is the irregularity of wood. Two handles taken from the same tree may not have the same grain pattern, causing subtle but often significant functional challenges. One of those challenges is grain orientation. A good axe will have the grain oriented so that it is parallel with the cutting blade of the axe head. Looking at the bottom of the handle can check this pattern. If the early and late wood lines are aligned parallel with the orientation of the blade, then the handle will be able to properly distribute the forces through the handle. If the pattern of the grain is diagonal or perpendicular to the blade, then there is more likely to be damage to the handle during impact. This is a significant issue when it comes to manufactured handles that are available on the market today, so it is advised to check the grain pattern of a handle before buying it in a hardware store. Another functional challenge of wood is called “run-off.” If rather than running the full length of the handle, the grain takes a turn and disappears off the side of the handle it is called run-off. Run-off can be structurally challenging because it can potentially cause parts of the axe handle to break off during impact (Kana 2015).

Grain patterns obviously play a significant role in the strength of an axe handle, and therefore also speak to the sustainability of the product. Considering the irregularity of wood, it may be beneficial to incorporate some type of lamination into the handle forming process. By including some form of lamination, it may be possible to create patterns for force management and proper distribution throughout the handle.

Other characteristics of handles include various shapes and lengths. Most store bought handles measure at 36 inches. This length provides the user with a significant amount of power during a strike. However, with increased length, the user sacrifices control and accuracy. This was later discovered to be essential for proper wood splitting. Handles have also been designed to come in curved and straight forms. Curved handles take ergonomics into consideration, but can also sacrifice accuracy.

## SHAPE AND TECHNIQUE

In addition to investigating the different form characteristics of axes, it was necessary to learn more about the proper use of axes.

Patrick Kana explained about the act of splitting wood, how trees grow, and how logs react to the forces of a wedge entering the grain (Kana 2014). He explained that the log of a tree is like a bundle of straws glued together, where the straws are the grains in the wood and the glue is the natural glue, or lignin. If you take that bundle of straws and turn it on its side, attempting to strike those straws with a wedge is essentially an attempt to sever those fibers and can be a difficult task. However, if you strike the bundle of straws with a wedge that runs parallel to the straws, you are not severing the straws, rather you are separating the glue that holds those straws together.

Figures 15, 15a, 16, and 16a illustrate this principal. It is shown that as the wedge runs through the straws, they separate from one another, causing the straws to split in what appears to be two sections. It is notable that the smaller, narrower wedge has a more difficult time splitting the fibers towards the edge of the straw bundle.

After gaining a better understanding of the properties that causes wood to split, it was necessary to learn about proper axe use. A meeting was arranged with John, a horse farmer and cabinetmaker local to Honeoye Falls, New York. The conversation was held in his workshop (Figure 17), which he designed and constructed himself, using many of the tools discussed and examined during the interview (John V. 2014)

John has spent a lifetime splitting wood to use as a heat source, and the resulting discussion led to a number of tips and habits that support safe and efficient axe use. John believes that good splitting is about accuracy. Knowing the log and how it will split is one of the first steps of splitting. When the carpenter prepares his log, he looks it over for knots, branches, or other deformities that will cause the wood grain to split in an irregular pattern. Then, with an experienced eye he will accurately strike the log so that it splits where he intended. For the majority of his splitting John uses a heavy maul (Figure 18). The one maul pictured in Figure 18 was likely between 6-8lbs based on feel and comparison to other maul heads that have been previously encountered. The maul is





Figure 17: Carpentry Shop, Honeoye Falls, NY



Figure 18: Splitting Maul

somewhat of a workhorse, meaning its shape is designed to specifically punch through logs just based on weight and form. It is an efficient tool, but according to the John it is heavy and a lot of the physical work translates into the shoulder region.

In addition to a splitting maul, John will sometimes use a lighter double bit axe. He likes to use double bit axes because of the symmetry and balance of weight. Most axes achieve this by using the weight in the poll,

but having the ability to perceive that balance seems to make it more desirable. The double bit also allows the opportunity to sharpen the blades differently, which benefits for multiple uses when using the tool out in the woods. When asked how he can tell which bit is the sharper end, John indicated the text stamped into one side of the axe. If the text is visible, it is known which edge is being used to cut.

When he uses a double bit axe to split full logs, John will first create a fracture in the log where he wants to split. Then he will follow through with another strike, using the technique of twisting his wrists at the point of impact. This twist transfers the forces perpendicular to the log, increasing the likelihood of a split occurring.

John also mentioned that the shape of the double bit axe is important for splitting and felling as well. A flat plane is more likely to get stuck in a tree. The axes he uses for this type of work typically have a raised section in the middle of the form. This will still get stuck in a log, but the amount of work needed to dislodge it is significantly less than it would be with the friction of a flat surface.

Another technique John employs is actually dulling his splitting blades rather than sharpening them. The reason he does this is related to the previous discussion about the bundle of straws (Kana 2014). Consider there is a log that has a knot causing an irregular grain pattern: when a maul or axe moves through the log like a wedge, it may encounter a twist or turn in the grain. If a sharp axe enters that twist or turn it will likely attempt to sever the grain in a cross-cut, probably resulting in the axe getting stuck in the wood. With a dull blade, rather than catch the grain and try to slice through it, the blade will follow the irregularity and split the log in a natural manner.

Though the carpenter did not have any full logs readily available, he used some already split logs to demonstrate his technique. Typically, John will not split logs directly on the ground for two reasons: it can damage his axe and it is ergonomically bad for his back having to bend over. John mounts the logs he plans to split on another larger log, like a platform. He said typically this piece is knee height because that is what he is comfortable with. Before the swing, he spreads his legs a little wider than shoulder width and lines up his body square to the striking position. In terms of efficiency, based on his stance, as long as

his strikes are accurate he is able to get more wood split in this position than he would going through a full rotational swing. Additionally, having a platform allows him to rest the axe head on the platform while collecting a new log to split. This saves him pre-swing energy expended since he doesn't have to lift the axe as high.



Figure 19: Double Bit Axe

The double bit axe with the yellow tape around the handle (Figure 19) is John's favorite axe due in part to the properties of the handle. The handle is wood, but it is slightly flexible in all directions. The character of this axe is exactly that, character. The product has acquired these characteristics through use over time, and it was encouraging to see the connection that there was between person and product.

In addition to the properties of the handle, he has learned many lessons about bringing his tools into the woods. It is quite noticeable that on both the double bit and splitting maul there is bright blue paint which was added by John. He said, "Imagine you are out in the woods in the Fall and you have an axe with the typical colored handles such as reds, oranges, and yellows. Granted they are fairly standard 'safety' or 'warning' colors, but if you set down your tool after a long day, you will never find it in the leaves and brush!" John selected the bright blue because no matter what season, it is a color that stands out in the natural world.

In addition to function, some discussions arose regarding safety, which is of paramount importance to this research. One key point was about

the length of the handle. John mentioned that a lot of injuries actually occur from the use of hatchets. This is because if a person swings a hatchet, which has a shorter handle, no matter where s/he follows through with the swing, it is difficult for that follow through to not end up somewhere on the body. With a longer handle, this is less likely to happen as the head of the axe will either hit the ground before hitting the body, or will miss the body through the end of the follow through.



Figure 20: Fawn's Foot Handles

The fawn foot handles (Figure 20) are great for beginners because they force the hands into a specific position, though with his experience John mentioned that he prefers a straight handle. He also stated that like with most handles, there needs to be a wider section on the bottom to act as a stop for the hand. One of the axes that he uses for taking the limbs off of trees is formed with a constant taper increase from head to bottom. He said the reason for this is so that there is a subtle stop everywhere on the handle, allowing him to choke up on the handle for close proximity work.

After meeting with John the carpenter, a meeting with local legend, Dave Jewett, a professional lumberjack competitor and woodworker





Figure 21: Dave Jewett's Christmas Tree Stand - Pittsford, NY

occurred. Jewett has broken over 25 world records and holds more than 30 world lumberjack titles. When Dave is not competing he spends his time creating wooden sculptures, furniture, and selling Christmas trees in Pittsford, New York (Figure 21).

When visiting Dave's Christmas Tree stand, which is located at the Pittsford Farms Dairy in Pittsford, New York, I caught Dave while he was eating lunch (Jewett 2014). After explaining my thesis approach, Jewett was adamant about the fact that there are not too many good splitting axes available on the market. To give some perspective about Dave's knowledge of splitting: he splits over 100 face cord of wood a year with an axe. At approximately 250 pieces of wood per cord, that's 25,000 pieces total. With approximately 1.5 swings per piece, that's 37,500 swings per year – before his competitive training. Dave mentioned that in total, he swings an axe approximately 45,000 times per year.

Jewett began by explaining what makes for an ideal splitting axe. He currently uses a 5-6 pound axe head. Dave said that he has had previous discussions with loggers who were working in the 1940's in Quebec who would use a 2.5lb axe head for splitting. Jewett mentioned that in a lot of cases these Quebec loggers were dealing with much smaller trees than you see now, so a heavier head is ideal.



Figure 22: Dave Jewett's wood splitting axe - width toe to heel



Figure 23: Demonstration of proper position for hanging steel

Next he began to discuss about the width of the blade, from toe to heel. Dave said that in a lot of cases, as is the issue with mauls, the blade width is too short. He used the example of striking into the center of a large diameter log with a maul. The log will be difficult to split this way, and the maul will get jammed inside the log, making it almost impossible to dislodge. This is called “being inside the wood” according to Dave. He says the solution to this issue is a wider blade. The optimal width for Jewett is a blade of 6 inches (Figure 22).

According to Jewett, the proper way to split wood is to do so by “hanging steel.” Hanging steel is a term that is used to represent the blade entering a log on the corner of the saw-cut edge so part of the blade is hanging off of the side of the log (Figure 23).

There are a couple of important reasons for hanging steel during the strike. The first reason is to avoid the axe head getting lodged inside the log. By striking into the edge of the log, the lumberjack is creating a smaller surface area for the axe to get stuck in, reducing the amount of post-ballistic energy expulsion needed to remove the axe in the case that the log doesn't split.

Another reason for hanging steel is to create a point of entry that requires less energy to initiate the split. For example, when tearing a piece of paper in half, typically it is started from the edge of the paper rather than the center because there is less fiber to separate and it requires less force. Similarly, this is the case with a log. The person

splitting should initiate the grain separation on a small, local point, rolling into the rest of the log to follow through with the split.

Dave's technique is different than the other experts that I spoke with. Nick Zdon prefers the splitting technique that involves twisting the wrist at the moment of the strike to redirect the forces within the log, similar to John's method when he uses a double-bit axe. I mentioned to Nick the method Dave's method of hanging steel and he was convinced that both his method and the hanging steel method are equally effective (Zdon 2015). Ultimately both techniques involve moving around the log to take off fillets, then working into the middle. The Finnish Vipukirves axe, which has the offset poll (weight), is designed to do the twisting work in Nick's technique automatically for the user. This can be successful, especially with European species, but Nick feels that an axe really needs to have the ability to do multiple jobs for the user. He said that "something gets lost when you move away from the inherent design of the classic American axe" (Zdon 2015).

In the continued discussion about form and technique, Jewett and I talked about the angle and girth of the axe head. He said that it needs to be narrow enough to penetrate, but thick enough to spread the fibers. He felt that the approximate optimal angle was 35-40 degrees.

Lastly we discussed the length of the axe head. Jewett feels that the best length for an axe head is 7-7.5 inches long. In a lot of cases the axe heads that you find in the hardware stores will be longer and Dave thinks that this is so manufacturers can keep people from breaking their axe handles. In order to avoid breaking handles, he said that people need to learn to hit the middle corner of the log and roll heel to toe – in other words, hang steel.

Jewett said that a splitting axe should not have a sharp bit. This was consistent with what John the carpenter discussed in my previous conversation (John V. 2014). The duller blade allows for grain separation as the axe head moves down into the log.

Next we discussed the length and shape of the axe handle. Jewett and almost all competitive lumberjack racers in the world will use an axe handle that is 29.5 – 30.5 inches long. One reason for the shorter handle is to increase accuracy. Most manufacturers issue a 36" handle,

which can increase speed of the strike, but significantly decreases the accuracy. This can cause people to mis-hit and break their handle (Jewett 2014). Dave explained that accuracy is important because you need to split a log based on your understanding of it. In other words, if there is a knot in the log he will go around it, creating fillets, rather than try to go through it. By attempting to split into a knot users are chopping through the grain rather than splitting it apart. If the axe handle is shorter, people will likely feel more comfortable landing the axe head where they want to strike.

Most of the power of a proper swing is generated from the core rather than in the extension of the arms, which is a common misunderstanding. Technique is important when it comes to landing the axe head on a specific target accurately. The axe head should follow a path towards the log that runs parallel to the center of the body. If the axe comes down between the eyes, the user is more likely to hit their intended location. Many users will strike a log off to the side of their dominant hand, but this decreases both power and accuracy. In order to engage the core, the axe head should rise up along the ear of the dominant hand, then come down along the centerline of the body. Jewett also slides his dominant hand up and down the handle during the lift and strike.

Jewett made a point reiterate that the swing needs to be relaxed. The person holding the axe needs to have a loose grip and soft hands. Good form is to keep the non-dominant hand tucked “in your pocket” with the deer foot - also known as fawn foot - of the axe handle against the palm of your hand (Jewett 2014). It is important to keep your elbows in during the various steps of the strike. This allows the person to generate more energy from their core. Dave mentioned that swinging an axe is like a boxer throwing a punch. They can throw an outside hook that creates more of an arc, but it has less power on impact. If the boxer keeps their elbows in close and jabs the punch using their body, there is a much stronger impact. Jewett uses an axe handle with a slight curve that allows him to push into it and increase the acceleration of the axe just before impact. He said that if your axe head covers 8 feet of distance throughout the entire swing, the most important part the swing is the last 2 feet. During the last 2 feet of the swing Jewett will break the position of his wrists and release his elbows allowing the axe to follow through.



## AXE MARKET

One of the most useful developments for understanding the axe market was discussing the primary customers for Best Made Co with Nick Zdon (Zdon 2015). Nick said typically they work with an urban and upper middle-class cohort who have property elsewhere in rural areas. This was also mentioned by Peter Dudley (Dudley 2015). Zdon said that Best Made does have customers who live in remote areas but mentioned that the majority of the market is not looking for a premium axe - which can be an issue for them because their axes are at a higher price point than most.

In addition to benchmarking, this discussion helped lead to the conclusion that the best competitive market option would be to design an axe that would be desired by middle-class people, who live in rural areas permanently and need a highly functional wood splitting axe.

As an important conclusion to my research, and segue into development, Zdon told me a story about one of Best Made Co's competitors, Gransfors Bruks. In the early 1990's Gransfors hired a new CEO, who implemented some serious improvements to the manufacturing of their axes. The biggest change was that they stopped painting the heads of the axe and left the forge finish. The only grinding/finishing that was done was right at the cutting bit. Zdon explained that removing the paint made the blacksmiths realize that they needed to do better work in the forging process, and if they didn't do a good job it would reflect on them personally. Similarly, the people who would grind and finish the axe needed to do a better job because their work was no longer being covered with paint. Some might argue cutting out these steps is just a ploy to save money, but realistically the consumer is getting a better product. Another company called Wetterlings also improved manufacturing by introducing high frequency furnaces into their system, essentially acting like high-powered microwaves. They additionally switched to hydroelectric power (Zdon 2015). Both of these examples tie back to telling a story and creating an "honest product."

## **SUMMARY OF RESEARCH**

The extent of preliminary research expanded farther than intended. Through literature review, discussions with experts and beginners, and the evaluation of the existing product market and manufacturing, I was able to create a thorough foundation for the beginning of development and product testing. It was assumed that more insight would reveal itself during the creation of physical prototypes and the evaluation of existing products.

# DEVELOPMENT AND EXPLORATION

## SAND CASTING

Creating both cast replicas and alternate iterations of existing axes was important for understanding the changes and methods that have impacted axes throughout time.

The first product that I cast was a contemporary hand axe that expands upon some of the earliest known axes. Early hand axes were chipped from stone (Heavrin 1998), but in a more modern perspective, I chose to use cast iron to create my own rendition of the product. This product was conducive to sand casting, which I will explain and highlight through the next few pages.

The first step, as with most types of casting, was to create or locate a positive form. In this case I chose to create the form using wood (Figure 24).

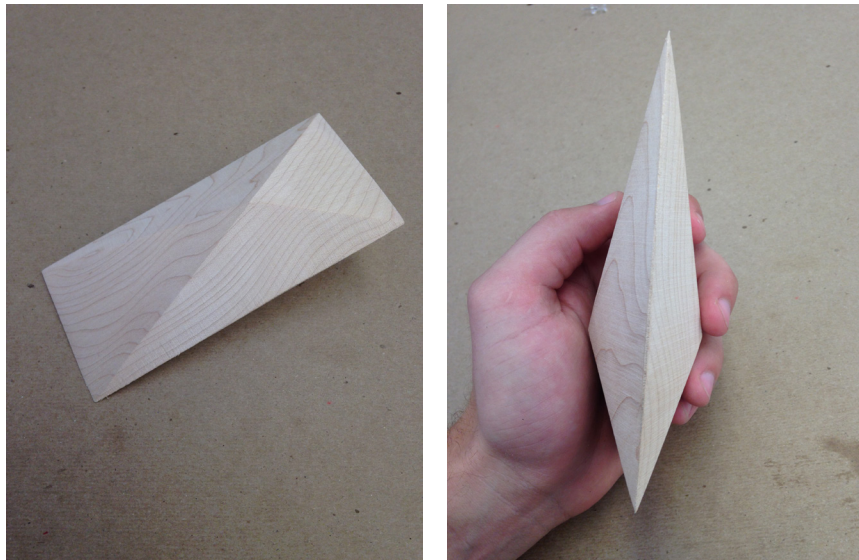


Figure 24: Wooden hand axe model

The second step was to create a flask to ram resin sand, which would create the mold for the match-plate. A match-plate is a plate of iron, or any other cast material of choice, which acts as a pattern maker. Cast into the match-plate is the positive form of both sides of the object. This way sand can be rammed on both sides of the match-plate at the same time making for a faster mold making process. The flask is a term used for the box that is created to act as the barrier for the sand to be rammed into (Figure 25). Flasks can be made from a number of materials – I

chose to use MDF and Particle Board in this case because it is cheap and easy to assemble/disassemble:

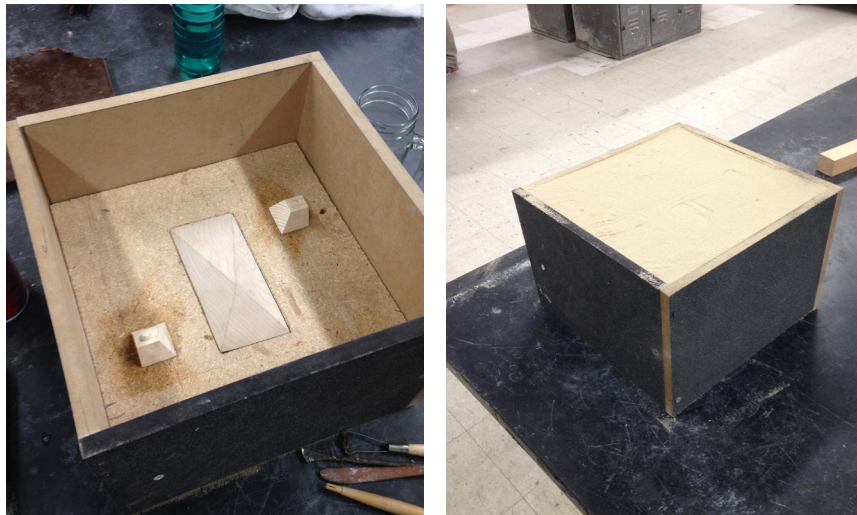


Figure 25: Wooden flask for sand mold making

As you can see in Figure 25, the flask is the square outer walls that surround what will become the mold. Half way down the wall of the flask is a leveled platform where the object lays. I cut a hole in the platform where the object was positioned so that the parting line (where the mold pulls apart) lays flush with the top of the platform. In order for a mold to pull apart properly, there needs to be a certain amount of draft, or angle, to allow the mold to slide off the part. If there is not proper draft the mold will get stuck on the object and the form will be permanently stuck in the mold material. This wasn't much of a concern for my particular product because the angle of the draft is fairly significant. This made undercuts, or areas on the form for the mold to get stuck on, a non-issue.

I also glued keys to the platform so that when the sand was rammed into the flask the keys would leave impressions. This was so that the mold could later be repositioned in the proper orientation for iron pouring. In addition, in order to keep the geometric form from falling through the hole of the platform, there is a thick layer of oil sand that is built up in the bottom half of the flask, creating support underneath. This is strictly for support purposes and was removed before ramming the second half of the mold.



Figure 26: Half finished mold

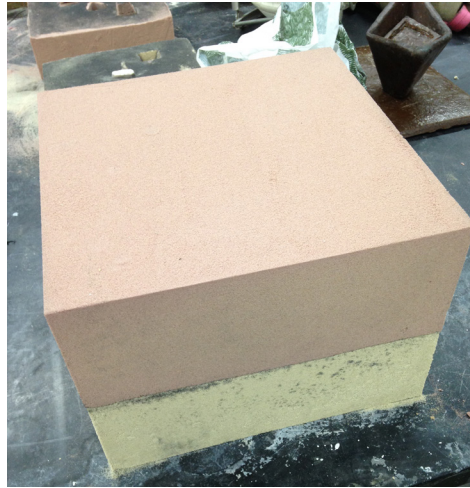


Figure 27: Finished sand mold

Figure 27 shows the finished sand mold. To create this type of mold there is a resin and catalyst that are mixed together with sand. The coloration difference in the top and bottom half are attributed to the type of sand used. These components are mixed in a large drum, then following the mixing process there is about a 5 minute working time where the sand needs to be firmly pounded into the flask to fill all voids. Once the first half is rammed and dry, the mold can be flipped to do the other side. I removed the geometric form for the purpose visualization in Figure 26, but it was replaced for ramming the second half. The black coating that can be seen is a layer of graphite dust that acts as a release agent for pulling the mold apart.

In order to create the match-plate, a layer of 3/8" thick sand shims are lined on the outer edge of the bottom half of the mold, then sandwiched between the two halves of the mold. This creates a gap between the two halves which ultimately fills with iron, creating a metal plate. Because this plate is in between the two halves, the top and bottom of the geometric form are also cast into the top and bottom of the plate. This allows the finished match-plate to become a stand-in for the particle board platform that was fabricated above when making the final piece. It simply allows for easier and repetitive mold making.

When the match-plate is finished, it is used to make very much the same





Figure 28: The inside of the sand mold

mold that was made above, with the exception of the space between. When the mold is opened, the match-plate is removed. Following the removal a large pour hole and three smaller vent holes are drilled to allow any air pockets to escape. These areas also fill with metal during the pour process and need to be removed post-pour.

In order to avoid the resin breaking apart when molten metal is poured into the mold, a mixture of graphite and denatured alcohol are brushed onto the mold. The alcohol is then torched off of the mold creating an enclosed coating. Following all these processes the mold is glued,



Figure 29: Finished iron hand axe prototype with sharpened edge

strapped, and poured. Once the pour occurs, the metal forms are broken out of the sand molds and ground using a hand grinder. The final product is shown in Figure 29.

It was surprising how comfortable this tool was in the hand. Though it was a primitive form, the size and shape are overall suited well for the hand. The bottom edge was ground and sharpened to act as a cutting edge, similarly to that of an axe. The only criticism was that the axe was heavy. Finding a balance between the weight of the solid iron hand axe and the original wooden form would be ideal. Overall it was a good exploration of material and form discovery.

## **LOST WAX CASTING**

In a different type of casting process called lost wax casting, I attempted to recreate both a Bronze Age Palstave and iron Viking Felling Axe. Information for both axes were taken from the book, “The Axe and Man” (Heavrin 1998). Both images were previously shown in Figure 8, upper right hand corner, and Figure 9.

### **Palstave – Bronze**

With both the axe and the palstave I had limited information about scale, so I tried to logically approach each with the knowledge that was available to me. The book stated that typically palstaves are approximately 250-500 grams when finished (Heavrin 1998). Because I was starting with wax for my creation process, I did a conversion using the weight relationship between wax and bronze to determine how much wax I would need to make a 450-500 gram bronze palstave. Following the conversion, I was left with a piece of wax that was approximately 2” wide by 5” long by 1/4” thick. This was shocking because it was so small in scale.

In the lost wax process, the initial wax form can be sculpted into almost any shape that is needed. In this case I started with a wax sheet that was poured into an open faced plaster mold like the one that is pictured in Figure 30. The plaster mold needs to be soaked in water before the wax is poured in so that when cooled, the wax releases from the mold.



Figure 30: Hot wax poured into plaster mold

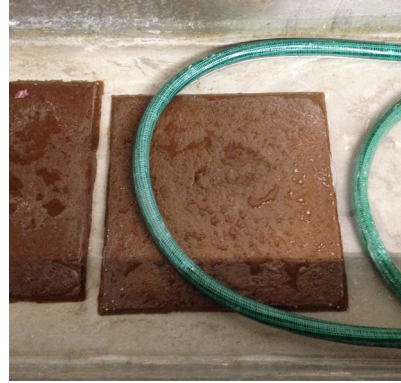


Figure 31: Wax cooling in sink

The wax is then left to cool and harden. This hardening process was sped up by running cold water over the wax once it transitioned from the liquid to the solid phase (Figure 31). Color change is also a good indicator as to when the wax is ready to be sculpted. This brown wax would go from a dark liquid, to a light brown solid, then back to a medium/dark solid when cooled. During the light brown phase, if the wax was sculpted it became sticky and stringy, kind of like the elasticity and stringiness you see in chewed bubble gum.

When the wax was cooled I was able to start sculpting. Figure 32 is an image of the small initial piece of wax that was used to begin the creation process for the palstave. In the image I have already started moving and altering the form, but it gives the general idea of what I saw when



Figure 32: Starting the sculpting process

starting this process.

Throughout the sculpting process I typically used clay carving tools and my hands to move the wax into the forms that I wanted. I would





Figure 33: Partially finished wax palstave

regularly reference the photo in the book to attempt to keep accurate proportions. Figure 33 is an image of my process about half way through.

When I finished my sculpted piece I needed to add a gate and sprues. The gate is where the molten metal will eventually enter the form and the sprues are where trapped air is allowed to escape to avoid getting bubble pockets in the finished piece. As part of the gate I created a cup which made a larger target for the pouring metal into the mold. In Figure 34 you can see the palstave and the attached gate and sprues. The sprues are the thin red pieces of wax that look like pipe cleaners, and the gate is the larger red rectangle attached to the brown wax cup. Interestingly,



Figure 34: Gates and sprues attached to wax palstave

in order to attach the gate and sprues to the piece, a method called wax welding was used. Essentially it involves heating a knife with a propane torch to red hot, then melting the wax at the points of contact so they merge as one piece.

Following the finished wax piece, it was time to start dipping (Figure 35). The finished mold is known as a ceramic shell. First the wax is sprayed with a tacky coating agent, such as hair spray. This was because when dipped into the water based silica slurry mix, the water will have the tendency to run off of the wax. After a few solo dips in the slurry to



Figure 35: Dipping wax piece in silica slurry to create the mold

initiate the coating process, the piece will start being dipped in slurry, then both fine and coarse sand. These steps are fairly specific and more time is required after each dip for the piece to dry. After several dips and approximately 3/8" of material build up around all parts, the piece is dipped once more and left to dry.



Figure 36: Finished bronze palstave replica

When the piece is fully dry, the mold shell is placed in a tub of boiling water where the wax is melted out leaving a cavity for pouring. Once the cavity is clear, the shell can be heat treated and poured with metal. You can see in Figure 36 the finished bronze palstave. During the pouring process there were issues with air escaping through my sprues so I ended up with air pockets near the thin part of the blade.

### Viking Felling Axe – Iron

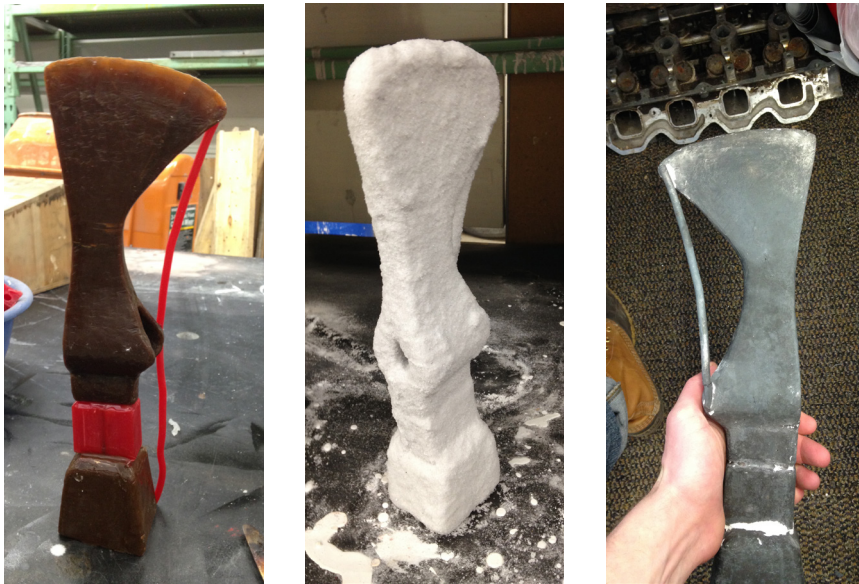


Figure 37: Accelerated view of the process of making the Viking Felling Axe



Figure 38: Finished iron Viking Felling Axe replica

The Viking Felling Axe used the same mold making process as the palstave, but instead of bronze I used iron as my final material. The scale was estimated by taking the round handle from an existing product such as a broom, which typically have gone through some ergonomic consideration in their design process. I then based the rest of the axe around the socket proportions.

## PRELIMINARY DESIGN CONCEPTS

### Handmade Handle

The first concept is the design of the axe handle. During some early splitting experiments I noticed some of the participants felt more comfortable stopping their sliding hand  $\frac{3}{4}$  of the way down the handle, rather than sliding all the way down to the grip hand. One theory was that the users feel that they have more control of the axe right before the strike occurs if their hands are separated slightly.



Figure 39: Painted handmade axe handle

This handle model was a test of form rather than strength capability, so I chose to use a softer wood to increase ease of carving. As part of my exploration I decided to create this handle by hand, then include more modern handle forming techniques in the future. I thought that the hand carving process would be important for understanding historical perspectives of the product. I started with a board of pine, cut it to the shape that I wanted on the band-saw, then used a spoke shave to create smoother curve relationships. There is a slightly raised area  $\frac{3}{4}$  of the way toward the base of the handle, creating a tangible stop in the wood (Figure 39). I also added some black paint for both aesthetics and the division of hand placement.





Figure 40: Cleaning process of old axe head



Figure 41: Hung custom handmade axe handle on old axe head

Following the forming of the handle, I was supplied with a rusty, aged axe head that my dad found in our barn in upstate NY. I decided to clean up the steel with a hand grinder and wire finishing bowl-brush (Figure 40). After uncovering years of despair, I revealed a stamp in the steel that said “Sid Axworthy.” Many axe heads have a stamped company brand similar to this one. Following the cleaning process I was able to join my newly crafted handle to the axe head. Based on the weight and form this axe would likely be more of a felling axe than a splitting axe.

That being said, I attempted to fell my first tree using some online tutorials and various sources of instruction. This was not my main focus for the thesis, but it was a good lesson in the area of control and accuracy. I was able to drop the tree close to the path which I had intended, but the strike zone on the tree was hacked and inaccurate. I attribute this both to my lack of skill, as well as improper grip. Throughout the process it was snowing, which results in a slippery axe handle. At the time I had gloves with rubber grips, but they became

coated in water, resulting in loss of control. I switched to my bare hands, which was better for control, but the cold air quickly caused my muscles and skin to become sore and restricted. At this point I switched to suede leather gloves. They became wet, but did not lose their grip ability. This was an interesting and unintended finding as a result of my felling experience.

### Dead-Blow Axe

The next concept was the Dead Blow axe, which plays with the physics of axe movement in order to improve splitting abilities. This axe is designed with a heavy weight on a track that shifts during the different stages of the strike. When the axe is brought up above the head to initiate the strike, the weight will be at the back of the track. As the swing begins, in theory, because the axe is moving at a constant velocity across the circumference of the swing, the weight should remain against the back of the axe head until point of impact. This phenomena can be related to the revolving water in a cup trick. If you tie a cup to a string, fill the cup up halfway with water, and swing the cup around in a circle, the water will stay in the bottom of the cup without spilling. Following the point of impact, which will slow the momentum of the axe head, the

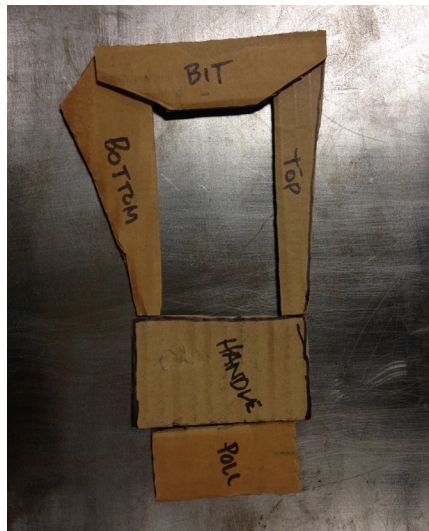


Figure 42: Axe head pattern



Figure 43: Plasma cutting pattern pieces



center weight will continue moving forward until acted upon by another force. In other words, when the cutting bit of the axe strikes into the wood, a split second later the weight of the poll will provide a secondary strike.

The prototype was created using welding techniques. A template was created using cardboard, then the pieces were cut out of sheet metal using a plasma cutter (Figure 42 and 43). One of the more innovative decisions that I made while making the parts for this axe head was to create handle sockets from standard pipe sections. This step was achieved by cutting the length of pipe that I needed, heating it with an oxy acetylene torch, then hammering it into the shape of the top of the axe handle. By using existing extruded forms to create required axe components, new methods for manufacturing coupe potentially be implemented, redefining existing perceptions of the process.



Figure 44: Assembly of pattern pieces



Figure 45: Continued assembly of pattern pieces



Figure 46: Fully assembled Dead Blow Axe

## Spring Splitter

The third concept was designed with the intent of using simple shapes, such as planes and piping, to create an axe head that could be welded and ground for testing. The form is meant to use the connections of the axe to create an opposing force that increases the splitting abilities of the axe head.

The first steps were to create a template (Figure 47), similar to that of the Dead Blow. When the plates were cut (Figure 48) I created a handle socket using pipe (Figure 49). After all the parts were created, and thick pieces of rod were cut to add as the poll weight, the welding process began. Once everything was fabricated, the axe head was ground to a point at the cutting bit, and prepared for testing by attaching the head to a pre-purchased wooden handle.



Figure 47: Axe head pattern



Figure 48: Plasma cut axe head pieces



Figure 49: Handle socket forming from pipe

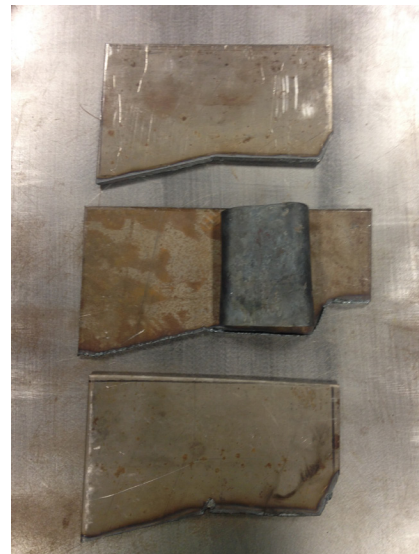


Figure 50: Assembly process 1



Figure 51: Assembly process 2



Figure 52: Assembly process 3

The design has two flanges that are connected at the cutting bit (Figure 53). The idea is that by striking a log, the metal compresses and pushes back against the wood, creating a spring reaction. Additional features that might increase this could be curved carbon steel inside the flanges that act like mini-springs. It was also possible that instead of increasing splitting, the flanges will just cause the axe head to get stuck in the wood.



Figure 53: Fully assembled Spring Splitter

## **SUMMARY OF DEVELOPMENT AND EXPLORATION**

The exploration phase of this thesis helped to create opportunities to compare and contrast between objects that are more conceptual as opposed to existing and accepted products. By making working prototypes early in the process, I was able to lay a foundation for testing and the evaluation of use.

# EVALUATING USE

To further my understanding of axes, I implemented multiple testing sessions documenting users of different abilities splitting wood. These users swung store bought axes and splitting mauls, as well as my hand crafted axes.

## TESTING STORE BOUGHT AXES

Testing of a 6lb splitting maul (Figure 54) began outside of the design studio. Each user had a different history of experience regarding axe



Figure 54: 6lb Splitting Maul

use. During the split tests I chose not to instruct the users about proper technique. This created an interesting opportunity to view natural, unedited use, especially for those who had never learned to use an axe previously.

The first user who tested the maul was me (Figure 55). At the time of testing, I was a 24 year old male, 178lbs, and 5'-8". My history of axe use extends back through my youth, and I have swung an axe almost every year since my elementary years. I do not consider myself an expert about technique, but it becomes obvious throughout the testing of various users, that experience and knowledge of technique are important in the splitting process.





Figure 55: 6lb Splitting Maul testing

Mauls are designed with a short blade and are meant to be split into the center of the log. They tend to be inaccurate which was a problem for some of the other users. During my testing experience I was able to generate enough force to split a log. At times the maul would get part way through the log and then get stuck and would be difficult to remove.

The second user who tested the axe was Behrad (Figure 56). Behrad was a 25 year old male, 229lbs, and was 6'-0". This was the first time that Behrad had the opportunity to swing an axe. Though Behrad had the size and ability to create a strong force, his technique and distance from the log affected his overall swing. At a point Behrad's follow through on the swing came dangerously close to hitting him in the ankle. This



Figure 56: User Behrad - 6lb Splitting Maul testing



raised a serious concern for new users and improper technique.

The third user who tested the axe was Stan (Figure 57). Stan was a 56 year old male, 182lbs, and was 6'-0". Stan previously split wood when he was about 11 or 12 years old, but hasn't used an axe since. Stan's form was good, but it seemed like having a log with a wider diameter may have affected the number of strikes he had to make before it split. Once the round log was split into wedges, it became much easier to split.



Figure 57: User Stan - 6lb Splitting Maul testing

the individual pieces.

The final test subject was Liana (Figure 58). Liana was a 23 year old female, 103lbs, and was 5'-2". Liana was another new user who had never used an axe before. Liana had a difficult time generating enough force to initiate a split in the log. Her strike was also inaccurate which caused her to overshoot the log.

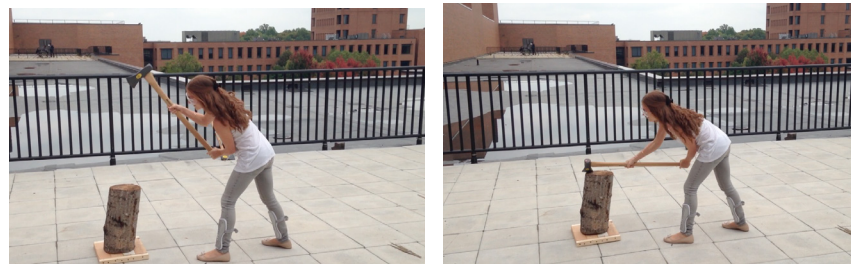


Figure 58: User Liana - 6lb Splitting Maul testing

In addition to the four users who tested the purchased splitting maul, I also was given a demonstration by John the carpenter. He showed me some of his technique for splitting using a maul. I also used a splitting maul in cold, wet conditions (Figure 59), which resulted in less control over the tool.



Figure 59: 6lb Splitting Maul testing cold, wet conditions

More tests were implemented using a store bought 3.5lb felling axe (Figure 60). The felling axe had a much wider blade toe to heel, with a narrower taper than the splitting maul.



Figure 60: 3.5lb Felling Axe

I wanted to see how the felling axe would hold up to splitting. I had Behrad, one of my previous users attempt to strike into a log (Figure 61). The narrow blade penetrated easily, but became stuck because of the amount of surface area that was jammed inside the log. This was similar to what happened when I personally tested the felling axe.



Figure 61: 3.5lb Felling Axe - stuck in the log

The only perceivable benefit of using a felling axe was the improvement in accuracy. I set up an experiment where I placed an apple on a log and attempted to split the apple (Figure 62). Not only did I split it, but I almost split it directly in half. I thought this might be attributed to some feature of the axe, but then I considered that it might not be the axe at all, rather it was the apple. By creating a smaller target for myself, I was able to more accurately maneuver the axe. This information would help feed into my future design process.



Figure 62: 3.5lb Felling Axe - splitting an apple



Although I didn't personally have a double-bit axe for testing, John the carpenter gave me a demonstration of his wrist twisting technique while using his own double-bit (Figure 63). This seemed to be an effective method for splitting.



Figure 63: Carpenter John splitting demonstration using a double-bit axe

## TESTING HAND CRAFTED AXES

The Spring Splitter axe head that I designed, which uses a spring mechanism to assist in the splitting process was tested for both functionality and user feedback.



Figure 64: Spring Splitter ready for testing

There were some clear positive outcomes of the Spring Splitting tests. The first essential component was that the axe split wood. I was unsure if the concept would work effectively and we confirmed this through our testing (Figure 65).

The axe head was significantly lighter than a splitting maul and performs essentially the same function. I also believed that the weight of the axe head could have been reduced even more by changing some of the inner materials or decreasing thicknesses.

The axe head didn't break immediately, but began to bend out of shape over time. The axe was welded in a few spots that encountered a significant amount of stress. Extra support would have been needed in order to avoid the bending.



Figure 65: Spring Splitter testing

There were distinct negative outcomes associated with the Spring Splitter as well. The welded weight distribution was irregular. Throughout the full revolution of the swing, there were points where the weight of the axe head made the user feel uneasy or out of control. I believed this was attributed to the heavy weight in the back causing an



Figure 66: Spring Splitter testing 2

unbalanced head.

It is unclear if the spring flanges of the axe served a purpose, or if it was the shape of the wedge that caused the splitting. In order to get a true evaluation of this, alternative recording methods would need to be used.

The most significant negative outcome of testing was the user rejection of the concept. When presented to users, people were hesitant about the product. People used it, but quickly chose their own splitting tool over the Spring Splitter. I attribute this to their knowledge of axes and what they are familiar with. There is likely a perception of what an axe should look and feel like, so drastic differences can cause negative reactions.



Figure 67: Dead Blow testing

The Dead Blow axe also had some significant positive and negative outcomes from testing. The shifting weight in the center of the axe moved (Figure 67), but not necessarily as intended. The physics of the model were successful and the weight stayed in position throughout the



swing revolution.

Unfortunately, the moving weight stayed in the wrong part of the pocket for some people. This was attributed to their personal method for splitting wood. People who lifted the axe above their head had success with the product, because the weight had the opportunity to fall to the back of the pocket before the strike phase of the swing began. On the other hand, people who use a full revolution in their swing would start the axe swing near their feet, causing the moving weight to stay in the front of the pocket through their whole swing.

For those where the weight did move, the impact caused a secondary strike as intended, but there was no apparent improvement in axe function. If anything, the moving weight caused the axe head to become more inaccurate at the point of impact because the shift in balance caused minor adjustments in control.

## **SUMMARY OF EVALUATING USE**

From the experiments and evaluations of axes and users, I was able to solidify some of the problems that were established while discussing objectives with various contacts. When narrowed into specific categories, the problems were divided into areas of proper technique, accuracy, and user education.

# DESIGN AND FABRICATION

The Sunder Axe design process required a design-build approach in order to be completed effectively. Throughout the various steps of the process I was required to learn, build, and design simultaneously. This presented a number of challenges which will be highlighted throughout this section.

## BLACKSMITHING AND SKETCHING

Traditionally axes have been made using blacksmithing techniques. Prior to the thesis study, I had no experience forging and smithing. With the anticipation that this would be time consuming, I began learning to smith early in the process. I started by meeting with Candance Martens, the Blacksmithing Director at Arc & Flame in Rochester, New York.

I approached the blacksmithing process thinking I knew about 80% of what it took to Blacksmith an axe head, and left realizing I started knowing only about 10%. I do believe that the learning process throughout my smithing was important for fully understanding the capabilities of material and its relationship with design.

Before my first session with Candace, she suggested that I buy some plasticine and try to move that with a hammer (Figure 68). I did this but it was soft and proved difficult because it would stick to the hammer. If I had cooled it off a bit, it likely would have moved more similarly to steel. This made hammer marks and strike patterns clear.

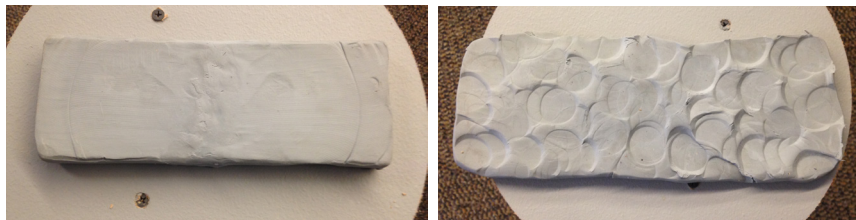


Figure 68: Smithing practice with clay

Our first lesson dealt with a propane gas forge and I learned about setup, safely turning it on and off, and breakdown. When working on this forge she taught me about the smithing process by showing me how to smith a small tomahawk from a railroad spike (Figure 69).



Figure 69: Smithing a tomahawk from a railroad spike

Following my first session I was given the opportunity by Arc & Flame to come and work whenever they had free hours. I had a practice session where I tried to follow traditional methods for axe making by hammering and folding a long, narrow piece of steel (similar to the methods in Figure 13). This proved to be difficult and the result was discouraging. Part of my frustration sprouted because I didn't have a true understanding of what is called forge welding. Forge welding requires a certain temperature level so the steel creates a honey-like surface to adhere to itself when folded.

During my next session with Candace I learned about the coal forge and forge welding. With the coal forge we were able to get the steel up to proper temperature for welding (Figure 70).

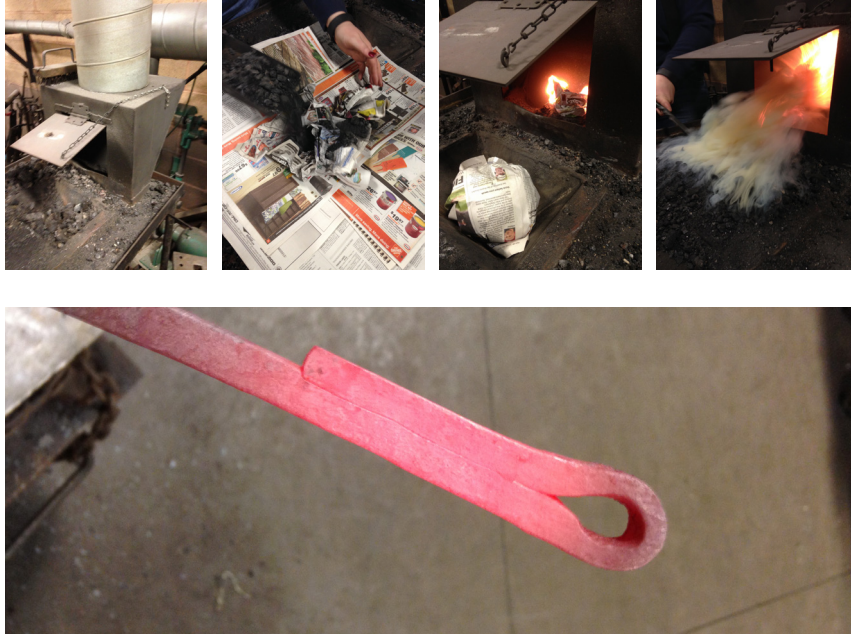


Figure 70: Forge welded piece

With the completion of the second session with Candace, I began feeling more confident that I would be able finish the axe head in time for my scheduled gallery showing. I practiced more with the coal forge, but found that controlling larger pieces of steel for folding was still difficult. I knew that I didn't have the technical skill that was needed to finish on time.

With this realized, I decided pivoting my approach and buying a large piece of high-carbon steel to shape into the form I needed would be the best direction to take. Again, this didn't turn out to be as easy as anticipated.

I had simultaneously been working on the design of the axe by sketching and then translating into CAD. My sketches were based around the knowledge that I acquired during my research, with the user being a primary component. To my process, the sketches became a quick way to visualize ideas, then concepts were implemented in various models and prototypes to validate design decisions. Though sketching is a minimal portion of the overall design process, it is still necessary to highlight how thought processes evolved.

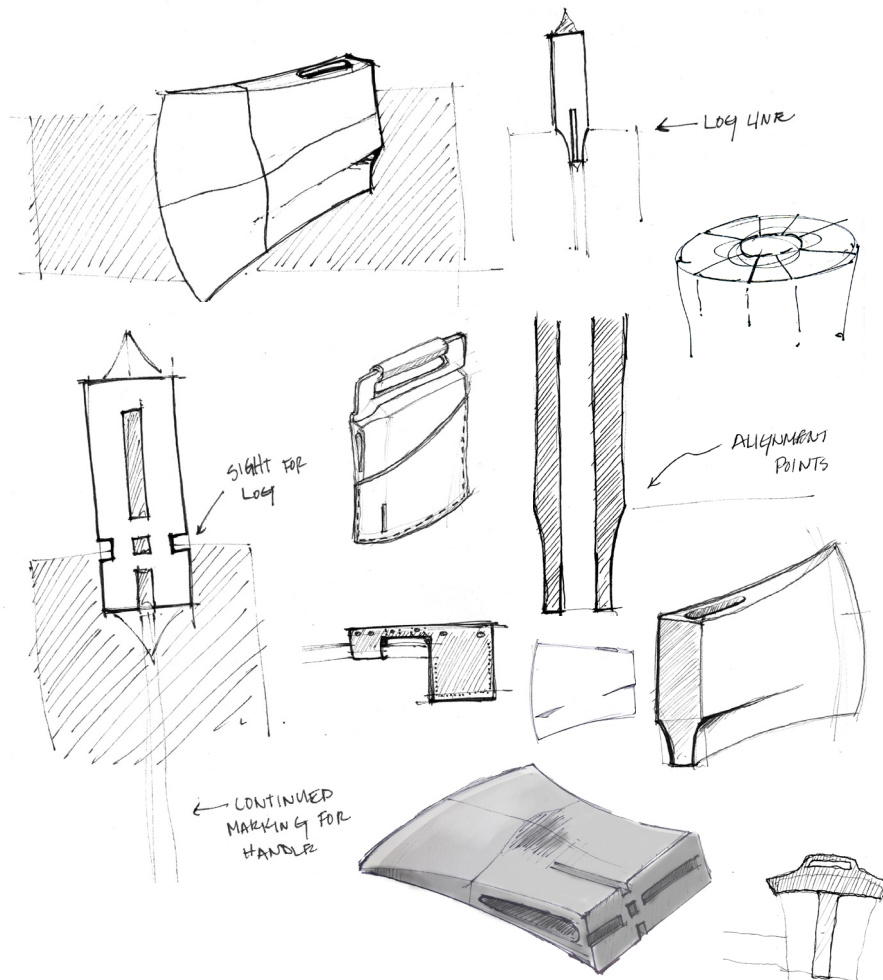
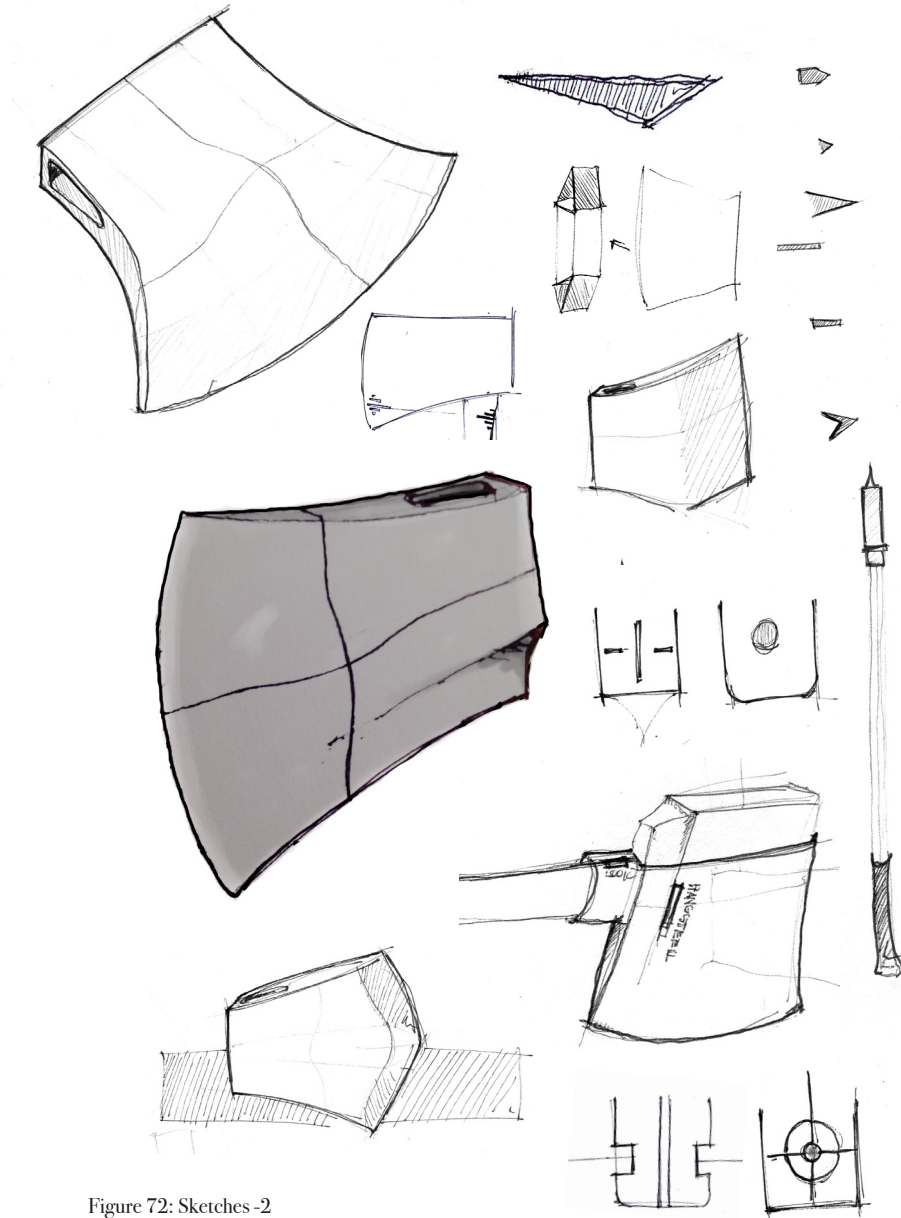


Figure 71: Sketches

Some of the key aspects I focused on during the sketching phases were features to encourage technique, habit, and user education. When some valid ideas were established on paper (Figure 71 and 72), I translated some of the ideas into Solidworks. This allowed for a general shape and size to be worked out. By using Solidworks I was also able to calculate the volume of the axe head I had designed, and then translate it into a steel mass based on the density. That way I knew approximately how large of a steel billet I would need to buy in order to make a similarly sized axe head. Solidworks also allowed me to export a file that could be 3D printed on the MakerBot. The full scale 3D print turned out to be helpful for visualization and size comparison later in the process.



Early in the process of Blacksmithing the large billet of steel. I made a poor mistake and set the hot axe head next to my tools. Exhausted from a long day of smithing, I was mindlessly putting away my tools. I reached for a tool, but instead got steel which was red-hot at about 800-900 degrees Fahrenheit. Luckily the hot axe slid out of my fingertips and





Figure 73: Burns on fingertips



Figure 74: Labeling hot items

only resulted in minor, but painful burns (Figure 73).

Following this mistake I became much more conscious of labeling and placement of hot metal (Figure 74). With a lack of options for tools for picking up such a large piece of steel (a 6 pound piece of 41-40), I found it difficult to control the piece and hammer at the same time. Through the gracious efforts of my professor, Matt Wicker, and my friend and peer Tim Copeland, we were able to work as a team to hammer a general shape that was about the same width as the 3D printed axe head (Figure 75). Together we were also able to create a series of punches to open the handle hole

Unfortunately, with steel lost to scale chips from hammering, the size decreased to smaller than my intended axe size. Regardless of this fact, I needed to start punching the hole for the handle. With the help of the shop tech, Rick Auburn, we successfully drilled a pilot hole for the punches to go through. After a grueling day of heating and punching, and getting through only half of the axe head with the first punch size, I was running out of time with regards to the gallery show so had to put the smithing to a halt.

Ultimately the smithing process was not brought to completion. During the next welding process I was able to get a successful and working axe



Figure 75: Forging the axe head

head prototype that suited my needs. I was fortunate to be able to work with metal in the way that I did so I could understand the complexity and mastery that it takes to be a true blacksmith.

## WELDING

When blacksmithing became too challenging to complete within the time restraints, I needed to develop another plan to reach my goals. I started by attempting to see how much it would take to have the axe head milled. Due to the complexity of the curves, it was going to be a time consuming and high cost process.

I called a few local metal shops to see how much they would charge me. Some of them denied my project all together because it was not feasible with their machinery. Another shop replied and said that it would require expensive tooling and they would need to machine it using plunge EDM processes. Plunge EDM requires pre-made electrodes to cut into the steel blank in order to get complex pieces. Finally I had a breakthrough with a company that said they could probably help me, but it would likely be best to do it by manually milling the steel. Sounding promising, and with 2 weeks before the show I was in good spirits. After waiting another half a week for a quote, the contact I was speaking with told me it would cost me \$2200 with a 6-8 week lead time for 1 prototype. Understandable, but not something that I could follow through with.

After the bad news I needed to formulate another plan. I could cast it in a different metal, but the mold making would be too time consuming. I

also considered 3D printing as a worst case scenario, but it wasn't ideal because I wanted to be able to take it out of the display case and test it later in the semester.

Finally, after speaking with 3 different professors, they all suggested the

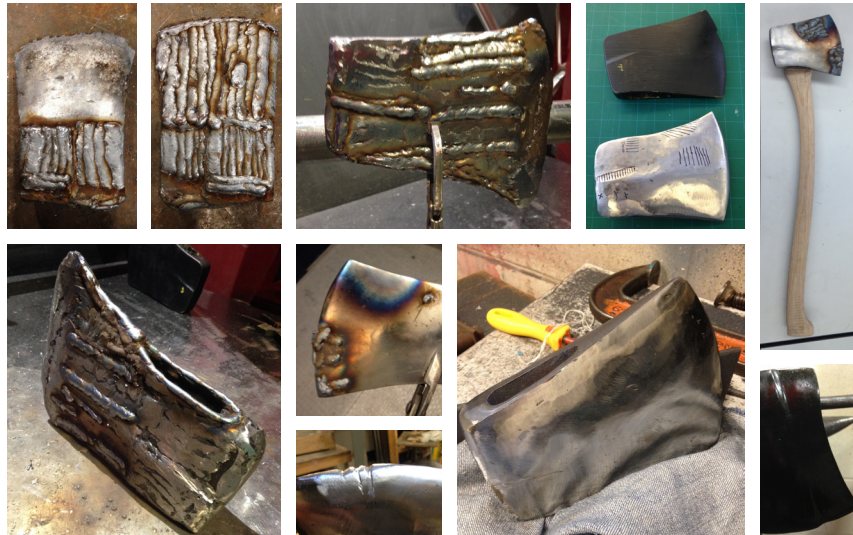


Figure 76: Welded axe head process

same solution – get an old, or store bought axe head, build up beads of weld on the surface, and grind it into the shape that I need. After almost 2 months of trials, challenges, accomplishments, and thinking on my feet, this seemed like the best solution considering my experiences with welding axes in the past semester.

The entire axe head was made using mild steel. This meant that in order to test it for functionality I would have to cut off, re-weld, and work a tool steel blade into it. The core of the axe was the Sid Axworthy axe head that was previously attached to my hand carved handle.

In my sketch and design process, I was determining a method for helping the user learn how to properly hang steel. This involved encouraging a proper starting stance, which could be achieved by including markers or notches in the blade. A notch was determined to be the best option because it was simple and easy for the user to properly orient themselves with relation to the log. More will be

explained about final design decisions later in the thesis.

Along with altering the 3D print, multiple iterations of the notch detail on the blade were tried, re-welded, and ground to new shapes. The axe head itself is blackened with linseed oil. This is achieved by heating the axe head and burning the oil into the grain. The linseed oil seals the steel to help prevent rusting. Following the application of oil, multiple layers of paste wax and shoe polish were added to buff and shine the surface. The entire process can be seen in Figure 76.

The interesting fact about the selected black finish is that the steel will reveal itself through use, similarly to the many subtleties that were designed into the axe to educate users.

## HANDLES

Alongside the axe head design-and-build phase, I also had to design and make the handle. In order to approach the design from a manufacturing standpoint I chose to use the CNC router to cut the handles. This allowed me to get a level of precision and uniform repetition when testing various sizes and forms.

Through a series of trial and error steps I learned a lot about the process and the challenges with that machine. I began testing by using blue foam. The first thing I determined was that if we planned to carve the wooden piece vertically, I would need longer cutting bits. With the shorter bits, the chuck was hitting the foam piece at the lowest cutting point. With foam this was fine, but with wood there could be significant damage to the handle or the machine. I also determined I would have to set up a better alignment system for flipping the piece. Eyeballing the zero point was not accurate enough and resulted in an offset of about 1/4 inch in the cut. It was also determined that the handle needed to be thickened for the next iterations.

Following making design changes and getting new bits we were able to try in wood. For the wood I chose white oak and ash. Axe handles are typically made from American Hickory, but it is a wood that required special order, so I picked up some comparable wood species that were



discussed with Patrick Kana (Kana 2014). The first attempt was using white oak. For this cut, fellow student and ShopBot manager, Tim Copeland, made a jig for aligning and properly flipping the piece. The first issue we came across was inaccurate centering of the piece on the jig, resulting of part of the handle being cut into one of the pegs we used for aligning. Another issue we faced was cutting time. Because of the depth of the cut when it was standing upright, the rough cut on the



Figure 77: CNC axe handle process

top half took over 6 hours. The reason we chose upright was because I designed a groove into the spine of the axe. If cut on the side, the groove would not be cut by the automatic process.

In an unlucky (but what turned out lucky) drop of the stop button face down onto the floor, the machine shut down and canceled in the middle of the program. It seemed unfortunate, but gave us time to think about what was happening, and had we continued the bit we chose for the finishing cut would have ruined the piece because it was tapered. Deciding to cut our losses, we started new the next day with the piece on its side. This time it was made from ash.

The ash handle was a success but still too narrow. Following this I



quickly made design changes and cut the final piece from white oak. The white oak handle which was finished and used in the gallery show was a success. Through trial and error we worked out a lot of details. The groove along the spine needed to be cut in by hand which I finished with a drill, chisel, dremel, and sandpaper. The handle was finished with linseed oil and mounted to the axe head using a poplar wedge. The entire handle making process can be seen in Figure 77.

Prior to the gallery show I chose to name the product, “Sunder Axe.” Sunder is a word which means to split apart, so it seemed suiting for this specific axe design.

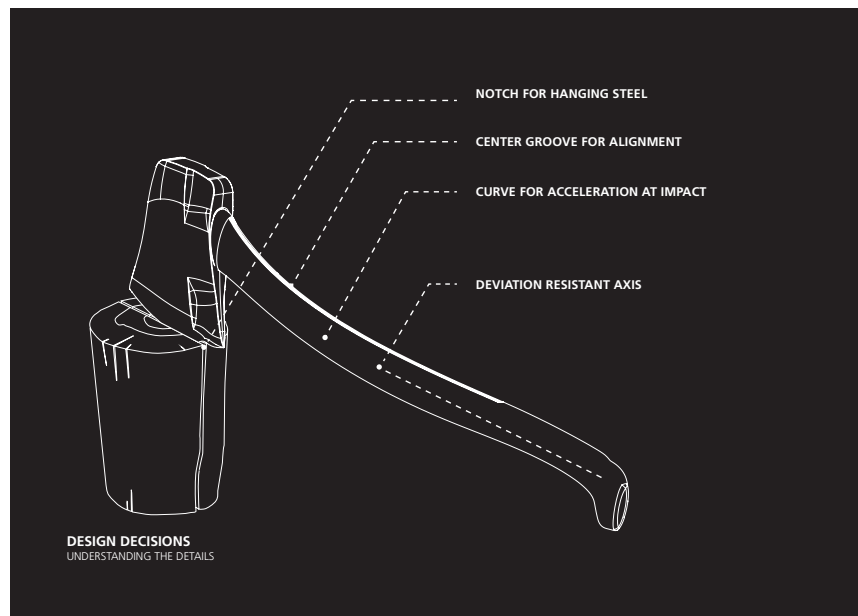


Figure 78: Design decisions

## DESIGN DECISIONS

The following design decisions were made based on the problems that needed to be improved from the research. These issues include proper technique, accuracy, and user education:

### 1. STRIKE-NOTCH FOR HANGING STEEL

A notch in the blade is strategically placed to properly align the user with the log. Striking the log on the near edge initiates the

split more effectively than punching through the middle (Jewett 2014)

## 2. CENTER GROOVE

The groove on the spine of the handle is meant to be a subtle reminder to strike with the axe aligned with the centerline of the body. This improves sighted accuracy.

## 3. CURVE

The most essential part of the swing is the last two feet before impact. The handle is designed with a curve so the user can push into it, increasing the acceleration of the axe.

## 4. DEVIATION RESISTANT AXIS

Curved handles typically have a grip axis aligned 10° behind the axe head (Cook 1981, p. 88). This improves comfort, but results in added deviation at the blade. Straightening this axis improves user accuracy.

These features alone are not enough to encourage habit and improve user technique. In order to achieve a full cycle I needed to add educational supplemental materials so the users would understand the characteristics of the axe. Without an educational component new users may use the tool improperly, potentially resulting in injury. In order to include this educational feature I created a user booklet, designed to guide users through the various safety tips, axe details, and proper technique. Below are the spreads from the booklet.

# SUNDER

## SUNDER AXE

DESIGNED BY TIMOTHY BROMM

Designed to improve the wood splitting experience by encouraging habit and safe use. This user manual explains the various characteristics and uses for your Sunder Axe.

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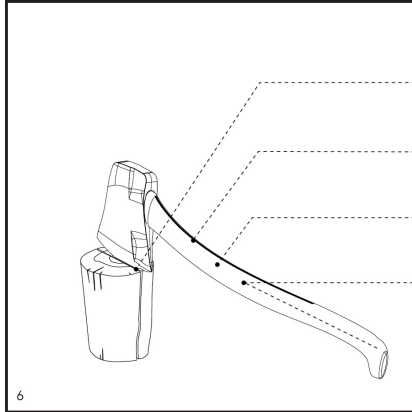
## GENERAL SAFETY

Wood splitting can be a dangerous activity if done improperly. This guide is meant to reduce the risk of injury and improve user knowledge of the Sunder Axe.

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## WHAT YOU NEED

- ☐ SUNDER AXE
- ☐ SAFETY GOGGLES
- ☐ GLOVES
- ☐ WIDE, KNEE HEIGHT LOG FOR SPLITTING PLATFORM



## PARTS OF SUNDER

### STRIKE-NOTCH FOR HANGING STEEL

The notch is strategically placed to properly align the user with the log. Striking the log on the near edge initiates the split more effectively than punching through the middle.

### CENTER GROOVE

The groove on the spine of the handle is meant to be a subtle reminder to strike with the axe aligned with the centerline of the body. This improves sighted accuracy.

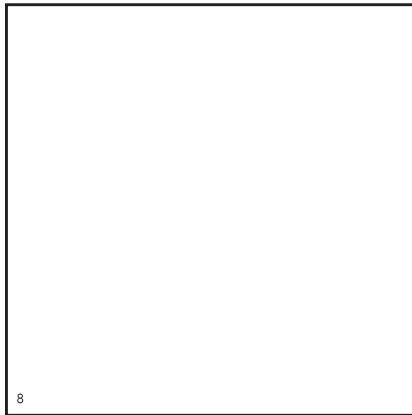
### CURVE

The most essential part of the swing is the last two feet before impact. The handle is designed with a curve so the user can push into it, increasing the acceleration of the axe.

### DEVIATION RESISTANT AXIS

Curved handles typically have a grip axis aligned 10° behind the axe head. This improves comfort, but results in added deviation at the blade. Straightening this axis improves user accuracy.

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## MAINTENANCE

### STORE IT DRY

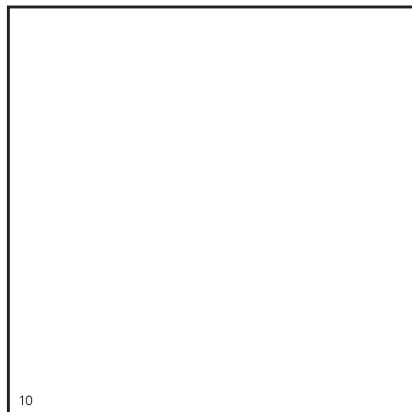
Keeping your axe out of the elements helps preserve the wood and steel.

### CUTTING EDGE

For splitting wood, the Sunder Axe cutting edge needs to be angled, but not significantly sharp. A sharp blade cuts through grain rather than splitting it, causing the axe to get lodged in the log.

### AXE HEAD

Apply oil occasionally to reduce rusting.



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## PROPER TECHNIQUE

1. INSPECT

2. ALIGN

3. TUCK AND LIFT

4. CENTER AND SLIDE

5. HANG STEEL

## 1. INSPECT

Inspect the log for deformities and irregular growth patterns. Avoid striking into areas including knots, crotches, and branches.

**Knots** can form in many ways, but are commonly caused from branches that have broken away and left holes in the trunk.

**Crotches** are areas where the major trunk has split into two distinct sections, creating split grain patterns.

**Branches** are growths of a tree where the grain pattern changes.

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**NOTE:** If irregular growth patterns are found, or a log is abnormally large, it doesn't necessarily mean that it can't be split. The user should work around the log taking off fillets, avoiding potential problem areas until they are the only pieces of the log that are left. Striking the center of a large log can cause the axe to get stuck or break.

## 2. ALIGN

Place feet shoulder width apart and place the Sunder **Strike-Notch** on the target point. With hands at the base of the handle, the arms should rest comfortably, and fully extended.

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## 3. TUCK AND LIFT

To initiate the swing, keep base hand "tucked in your pocket" and place the guide hand (dominant hand) just under the axe head. Keep the axe close to your body and bring the axe up past your ear.

**NOTE:** Keeping the axe close to your body improves control

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## 4. CENTER AND SLIDE

Continue to lift the axe over the center of your head, then begin to drive your base hand toward the log. At this stage begin to push into the curve of the handle with your guide hand, generating necessary acceleration for impact.

**NOTE:** Be sure to keep the **Center Groove** of the handle centered between your eyes for improved accuracy

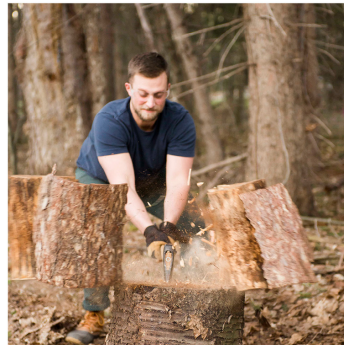
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## 5. HANG STEEL

Follow through with the strike and remember to strike your near edge target. Hanging steel simply means that the area below the **Strike-Notch** hangs off of the near side of the log, ensuring that an edge strike occurs.

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# SUNDER

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## GALLERY SHOWS

The Sunder Axe prototype was shown in two gallery settings. The first was an exhibit in the Bevier Gallery on RIT's campus, which was shown alongside other graduate theses projects. This showing was a good opportunity to both celebrate the work and gather feedback from others regarding the project. The second showing was at the Imagine RIT festival in the University Gallery. The second show had less of a crowd, but also provided some enriching conversations about the product.



Figure 79: Exhibit

## PHOTOGRAPHY

Professional photography of the product was also taken in order to preserve the initial visual appearance of the product before testing. The results can be seen in the images of Figure 80.



Figure 80: Professional photography

# TESTING

Testing the product was essential for the validity of the thesis. The initial tests were conducted based on the predefined techniques that were outlined in the user guide. Also, in order for the axe head to work properly, a high impact steel edge was welded into the preexisting blade. This required that the existing blade be ground back, built up with steel weld, then reshaped to the same notch form.

One of the largest initial functional concerns was the notch in the blade. Throughout the design process there was uncertainty about whether adding this feature would sacrifice some functionality. Needless to say, this was a non-issue in testing. The notch worked well as an alignment feature and did not sacrifice any functionality.



Figure 81: User testing



During the testing, logs of different sizes, drynesses, and compositions were used for splitting. This gave a range of scenarios for me to challenge the subtle design characteristics of the axe.



Figure 82: User testing - 2

Overall, the split testing was successful. In some cases the grain of the log was difficult to split and the axe would get stuck. Anticipating this, I had designed a crown into the face of the axe head to create less surface contact between the axe and the wood. This required less energy to remove the axe from the log.

The alignment notch was successful for taller logs, but anything shorter would have had issues catching on the edge of the log. This is partly attributed to the method that I chose for fabricating the axe. The handle



was hung on the axe head slightly closed, which means the blade is tilted too far toward the handle. Because I used an existing axe head as my core, I was limited by the position of the existing handle hole. If this angle were opened more there would be more success with shorter logs.

For this specific test I hadn't implemented the groove into the handle, so I painted a black marker line to simulate the visual effect. The shape of the handle worked well and the control was accurate.

In order to get more thorough results, future testing using people of different abilities and demographics would be required.



# CONCLUSION

By evaluating axe design based on tradition, functionality, and product use I was able to establish a series of problems related to current axe designs. These problems included an understanding of proper technique, accuracy, and user education. In order to address these problems, I used findings from the research and user testimonials to design and develop successful solutions. These solutions were then field tested to verify their validity.

Future exploration might include the evaluation of a wide demographic of users. It will also be important to receive and evaluate feedback related to the success of educational materials. Lastly, various manufacturing methods would need to be considered before this product potentially goes to market.

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Patti Moore - World-Renowned Designer and Gerontologist  
John V. - Carpenter  
Melissa Moukperian - Adjunct Professor, Textiles  
Elizabeth Kronfield - Associate Professor Fine Arts, RIT  
Dave Jewett- Professional Lumberjack Competitor  
Lt. Michael Dinsmore - Safety and Fire Prevention Lieutenant, Henrietta Fire Department  
Peter Dudley - Manager of Axe Shop, Best Made Co.  
Nick Zdon - Director of Customer Experience, Best Made Co  
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Tim Copeland – Industrial Design Student and CNC Shopbot Manager  
Kyle Blalock – Sculpture Student, RIT  
Kelly Wilton – Sculpture Student, RIT  
Zach Dietl – Sculpture Student, RIT  
Stan Rickel – Graduate Director, ID, RIT  
Josh Owen – Department Chair, ID, RIT  
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